§36. Improvement of Weight Density and Thermal Conductivity of Hydride Neutron Shielding Material

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In a fusion reactor, a thinner radiation shield layer must be installed to reduce a reactor size. Previous neutronics studies indicate that combinations of ferrite steel and boron carbide or ferrite steel and water, tungsten carbide, etc. can be candidates of the effective shielding materials. Metal hydrides, such as titanium, zirconium, and vanadium hydrides, are focused as the shielding material[1] because they can include higher density of hydrogen atoms than liquid hydrogen. It is difficult to fabricate the bulk non-crack metal hydride because of the brittleness and large volume change in the hydrogenation. Fig. 1 shows Zr-H binary phase diagram with the normalized volume change.

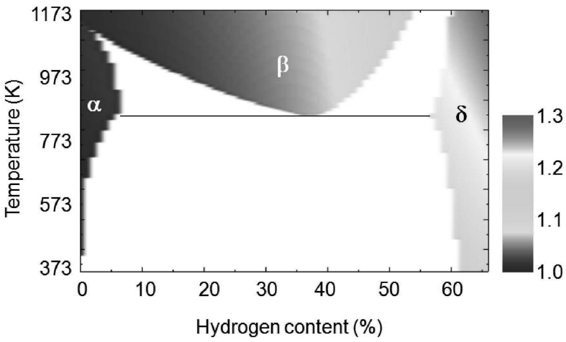

Fig. 1. Zr-H binary phase diagram. α, β, δ are α-zirconium, β-zirconium and δ-zirconium hydride, respectively. The colors represent volume change from α-zirconium.

The volume change in α-zirconium to δ-zirconium hydride phase transformation reaches about 20 %, which easily causes the cracking in the sample. Centimeter-sized bulk hydrides can be obtained by careful hydrogenation, however, much larger size of hydrides is required for neutron shielding materials in a DT fusion reactor. Previously, to simplify the fabrication process, we have tried to make dense hydride pellets by cold-pressing from their powders. About 90 % of theoretical density was achieved by cold-pressing with about 1 GPa pressure for both titanium and zirconium hydrides[2]. It is noted that the titanium is significantly softened by hydrogenation[3]. Young's modulus of $TiH_{1.66}$ is about a third of that for metal titanium. The softening effect by hydrogenation might provide the high density only by the cold-pressing. It means that the pressed hydride pellets had a large plastic strain. Before evaluation of the hydride-metal composite materials, the strain was observed by EBSD analysis in the present study.

Commercial ε-titanium hydride powder (Aldrich, 99 % purity) was pelletized by cold-pressing with pressure of 50 MPa or 400 MPa. The density was 63% and 83 % of the theoretical density, respectively. The pellet surface was observed by SEM (JSM-6500F, JEOL) and attached EBSD (OIM, TSL).

SEM images of pressed titanium hydride pellets are shown in Fig. 2. The particle shape in the pellets remains the same from starting powders with the pressure of 50 MPa. The low density pellets easily break by hand. The pressing with 400 MPa strongly deforms the particle shape and the pore region becomes small.

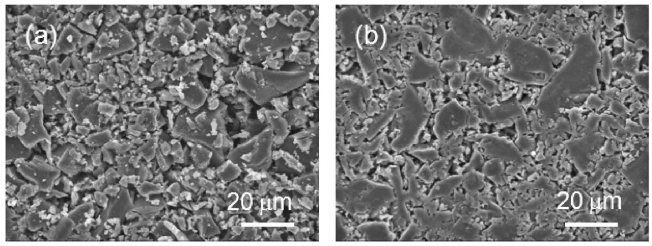

Fig. 2 SEM images of titanium hydride pellets pressed by pressure of (a) 50 MPa, (b) 400 MPa.

To estimate the particle deformation, EBSD observation was performed for surface of pellets. The Inverse Pole Figure (IPF) map is shown in Fig. 3. The color in the map reflects the crystal orientation of the particle. About a half region shows finely- and randomly-distributed color due to the surface roughness and small particle diameter. The crystal orientation cannot be observed exactly in the area. On the other hand, there are several small areas with similar color. It shows the hydride particle region. The color in each particle gradually changes. It means the crystal direction gradually changes, which indicates that these particle include elastic or inelastic strains[4] caused by the cold-pressing. Meanwhile, colors of the particle region seem to be distributed unbiasedly, which indicate that the crystal texture is not formed for this sample.

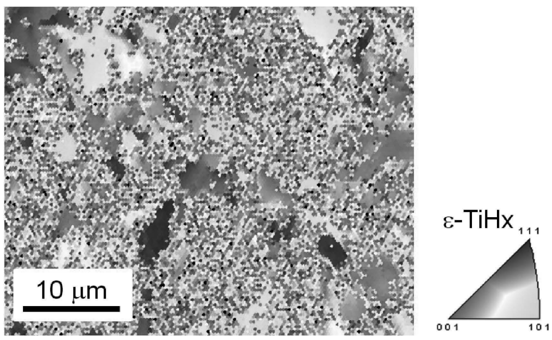

Fig. 3 IPF map of titanium hydride pellet pressed by pressure of 400 MPa.

1) Tanaka, T. et al : Fusion Sci. Technol., accepted.
2) Muta, H., Tanaka, T. et al. : Plasma Fusion Res. 10 (2015) 021.
3) Setoyama, D. et al. : J. Alloys Compd. 381 (2004) 215.
4) Kamaya, M. et al : Nucl. Eng. Design 235 (2005) 713.